Evidence for an Infrasound Waveguide

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Abstract

On May 30, 2005, eight strongly dispersed infrasound signals were recorded at one seismo-acoustic array in the Republic of Korea. Phase-matched filtering (Herrin & Goforth, 1977) and a forward modeling technique were used to determine the nature of the dispersion. The most likely explanation for these dispersed infrasound signals is that the dispersion is due to propagation down a low-velocity waveguide. This can be characterized as an ephemeral "SOFAR" layer in the atmosphere.

Discussion

The BRDAR seismo-acoustic station is located on an island off the northwest coast of the Republic of Korea (Fig. 1). BRDAR is composed of five elements of vertical GS-13 (1 Hz) seismic instruments in the vaults and 13 elements of Chaparral acoustic gauges. Each acoustic gauge is connected to a 10-element flexible hose array. The seismic and acoustic signals are digitized at 40 samples/sec. This station is part of a research effort by Southern Methodist University and the Korea Institute of Geoscience and Mineral Resources (Stump et al., 2004).

On the early evening of May 30, 2005, eight strongly dispersed infrasound signals were recorded in a period of about 11 minutes. All eight arrivals had an estimated back-azimuth of about 306° indicating they came from the same source area.

The signal with the best signal-to-noise ratio was selected for detailed analysis. Figure 2 shows this signal and the preceding noise in the top panel. The spectra of the signal and noise are shown in the lower panel. There is good signal level above noise from about 1.8 Hz to the Nyquist cut-off filter at 16 Hz. The signal spectrum is smooth to about 10 Hz. At higher frequencies the spectrum is scalloped, indicating possible interference. The shape of the spectrum suggests a broadband, impulsive source.

The nature of the dispersion suggested that the eight signals might have traveled down a low-velocity wave guide. In May, warm air moving over a cold ocean could have led to an inversion near the sea surface. Based upon phase velocities estimated from delays across BRDAR and the results of phase-matched filtering (Herrin & Goforth, 1977), we

constructed the following model by trial-and-error forward modeling. We treated the ocean surface as a rigid boundary overlain by an 80m thick cold layer with sound speed of 0.338 km/sec. Above the layer we assume a half-space with speed of 0.344 km/sec. These speeds imply a temperature of 10° C in the layer and 20° C in the half-space. Weather data from the island (http://www.kma.go.kr/child/lession/weather_search.jsp) varies from 22.5° C to 14.7° C, which shows that 20° C is a reasonable value for the temperature at that time. Because of the short wavelengths of the infrasound signal, we did not need to consider the normal lapse rate of temperature above the layer thus justifying the assumption of an upper half-space.

The dispersion characteristics of this model are given by the phase and group velocities of the fundamental and first higher modes as shown in Fig. 3. Note that the higher mode energy would arrive before the group velocity minimum of the fundamental mode producing interference and spectral scalloping.

The phase-matched filter was used to extract the fundamental mode. The original signal and the fundamental mode are shown in the top and middle panels of Fig. 4. The signal that remains after subtraction of the fundamental mode is shown in the bottom panel. We believe this energy is from the 1st higher mode. This energy would be narrow band from about 10 Hz to the cut-off at 16 Hz and would interfere with the fundamental mode energy. The spectrum of the signal shown in the bottom panel of Fig. 4 is shown in Fig. 5. The bandwidth of residual matches with that of the 1st higher mode group velocity dispersion curve.

Based upon the group velocity predicted by the model, we estimate the source of the studied signal, and probably the other seven signals, is about 65.3 km from BRD00 on an azimuth of about 306° from the station. To our knowledge, this is the first set of clearly dispersed infrasound signals recorded anywhere. We conclude that the most likely explanation for the dispersion is propagation down a low-velocity waveguide. This can be characterized as an ephemeral "SOFAR" layer in the atmosphere.

References

Stump, B., M.S. Jun, C. Hayward, J.S. Jeon, C. Il-Young, K. Thomason, S.M. House, and J. Mckenna (2004). Small-aperture seismo-acoustic arrays: Design, implementation, and utilization, Bull. Seism. Soc. Am., 94(1), 220-236.

Herrin, E. and T. Goforth (1977). Phase-matched filters: application to the study of Rayleigh waves, Bull. Seism. Soc. Am., 67, 1259-1275.

Figures

Fig. 1. Map of Korea with detail of BRDAR. Red triangle represents the location of BRDAR in the Republic of Korea. Blue triangles represent Chaparral acoustic sensors. Yellow triangles represent GS-13 short period seismic instruments.

Fig. 2. Detail of the dispersed signal analyzed in this study. The top trace is the comparison between the signal (red) and background noise (blue) for the third infrasound signal. The bottom trace is the comparison of spectrum between signal (red) and background noise (blue).

Fig. 3. Phase and group velocity for fundamental and 1st higher mode based on wave guide model. The letter "c" represents phase velocity dispersion curve. The letter "U" represents group velocity dispersion curve.

Fig. 4. Results of phase-matched filtering showing signal, fundamental mode, and residual from the top to the bottom. The vertical scale is microbars for each trace.

Fig. 5. Spectrum of residual after extracting of the fundamental mode. Top trace is the comparison between residual (red) and background noise (blue). Bottom trace is the comparison of spectrum between residual (red) and background noise (blue).

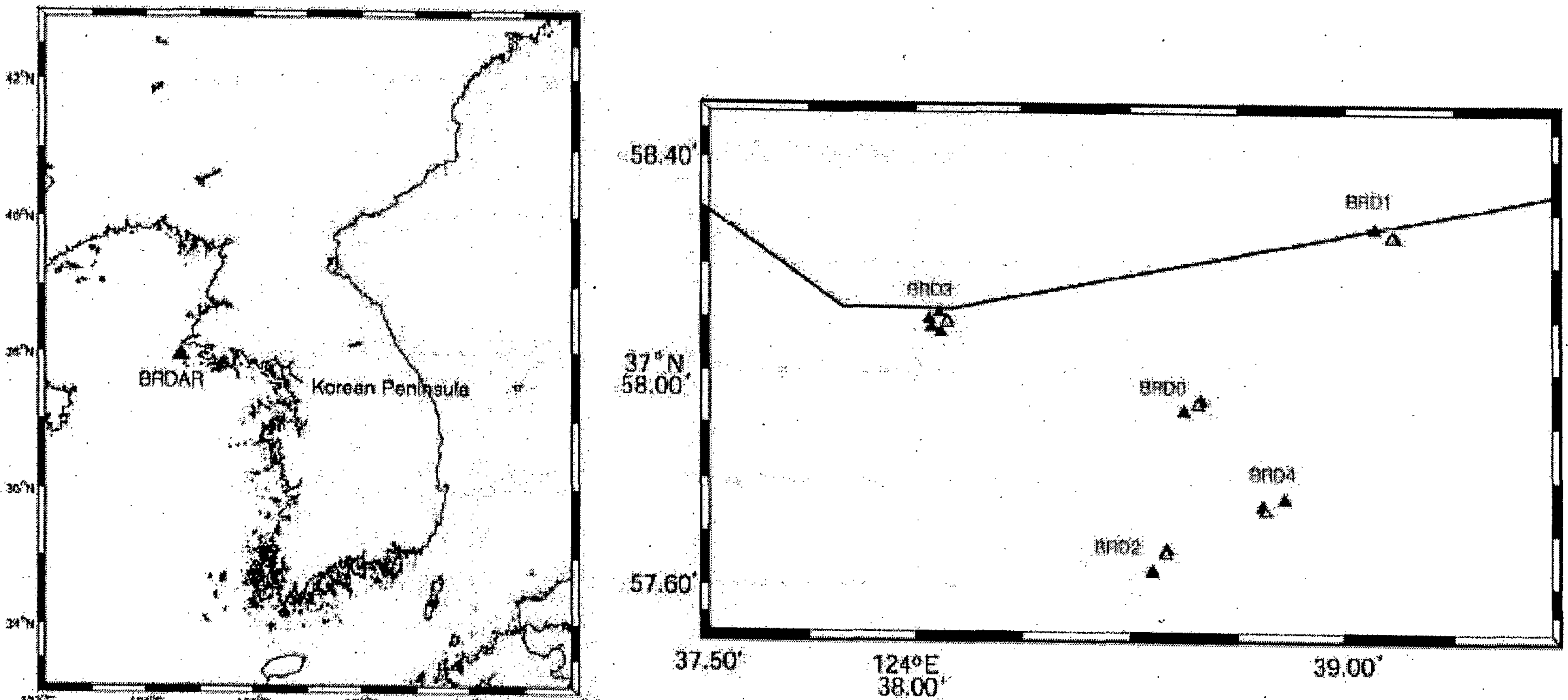

BRDAR
Korean Peninsula
58.40'
37°N
58.00'
57.60'
37.50'
124°E
38.00'
39.00'
BRD1
BRD3
BRD0
BRD4
BRD2

Figure 1.

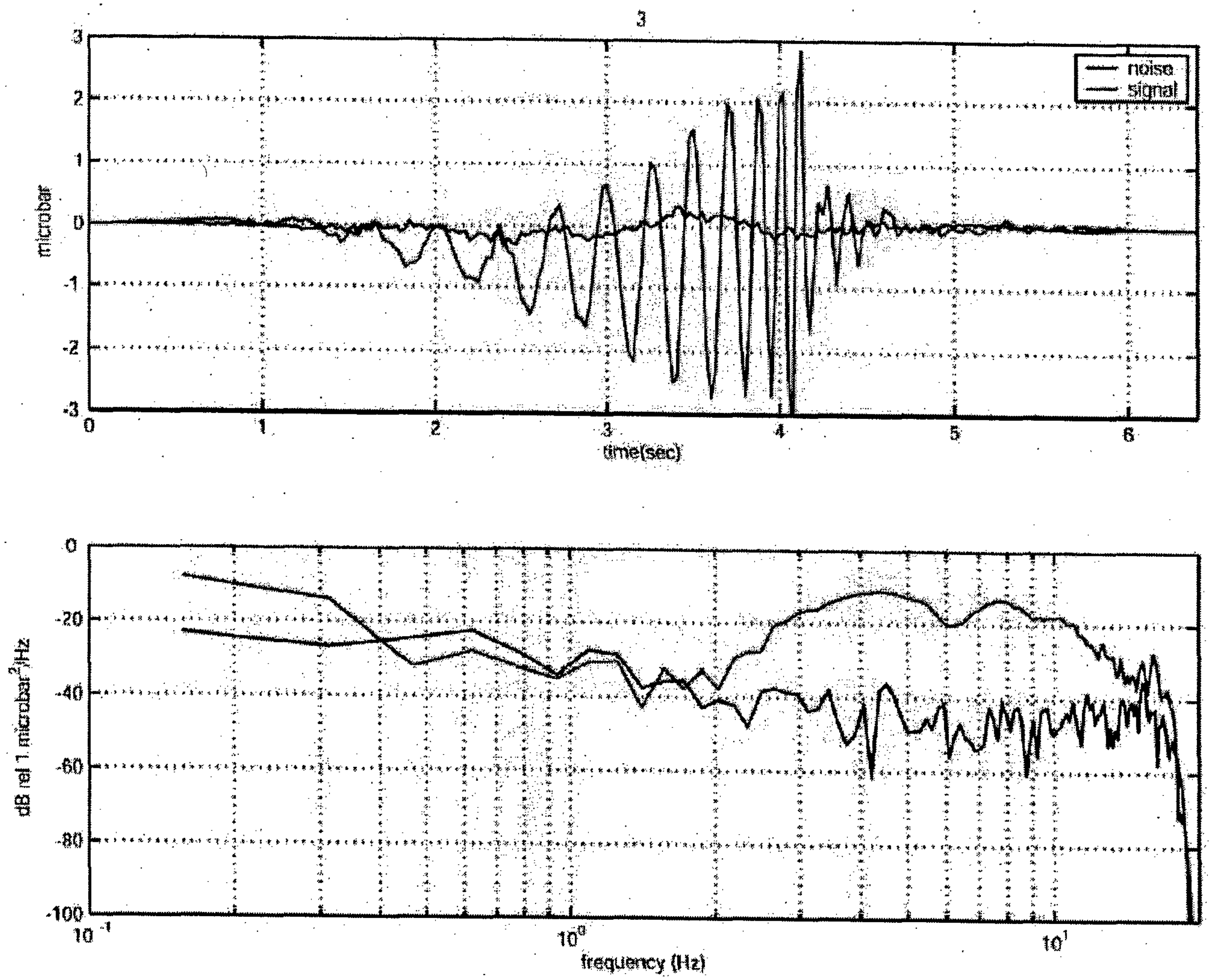
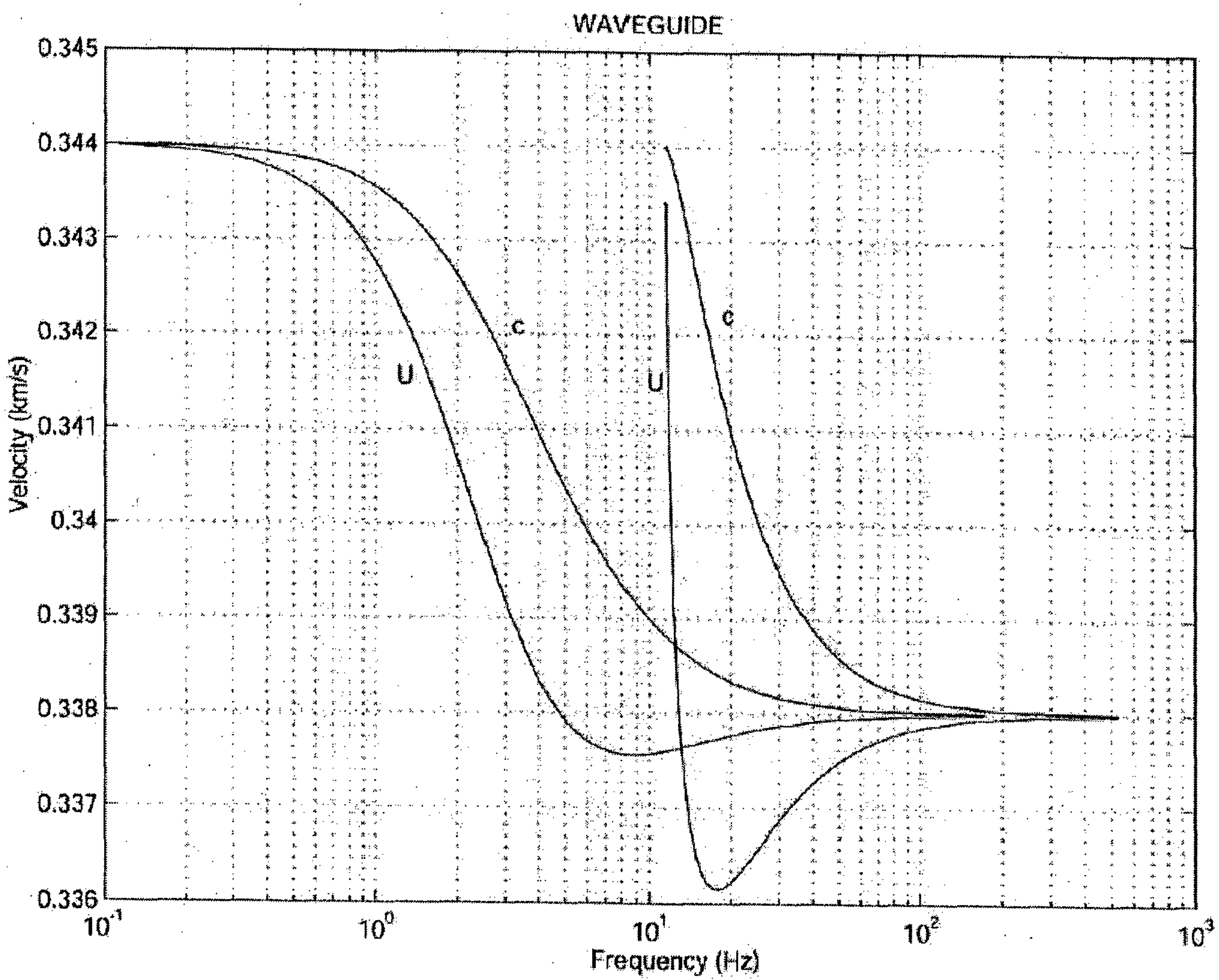
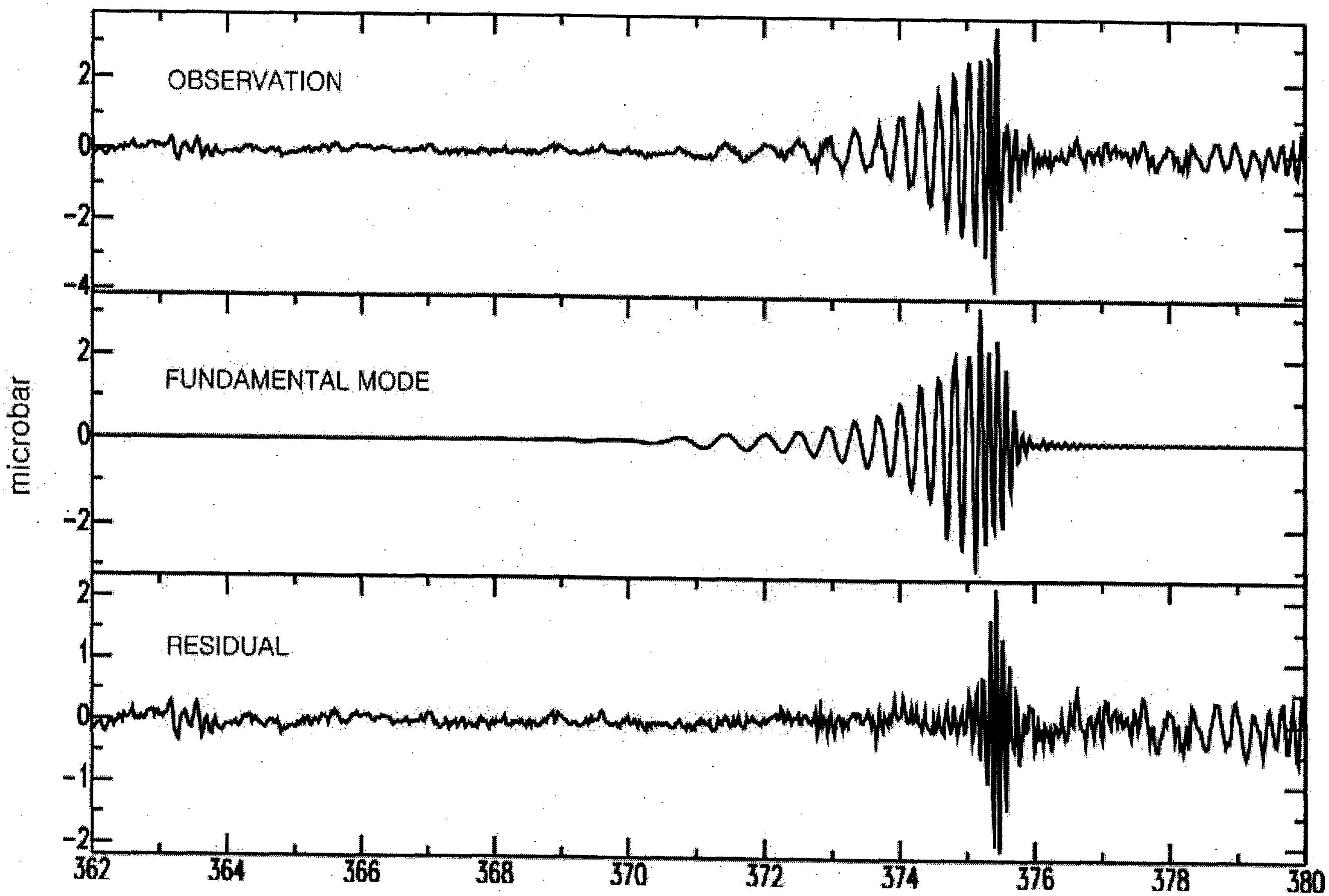

3
noise
signal
microbar
time(sec)
dB rel 1 microbar^2/Hz
frequency (Hz)

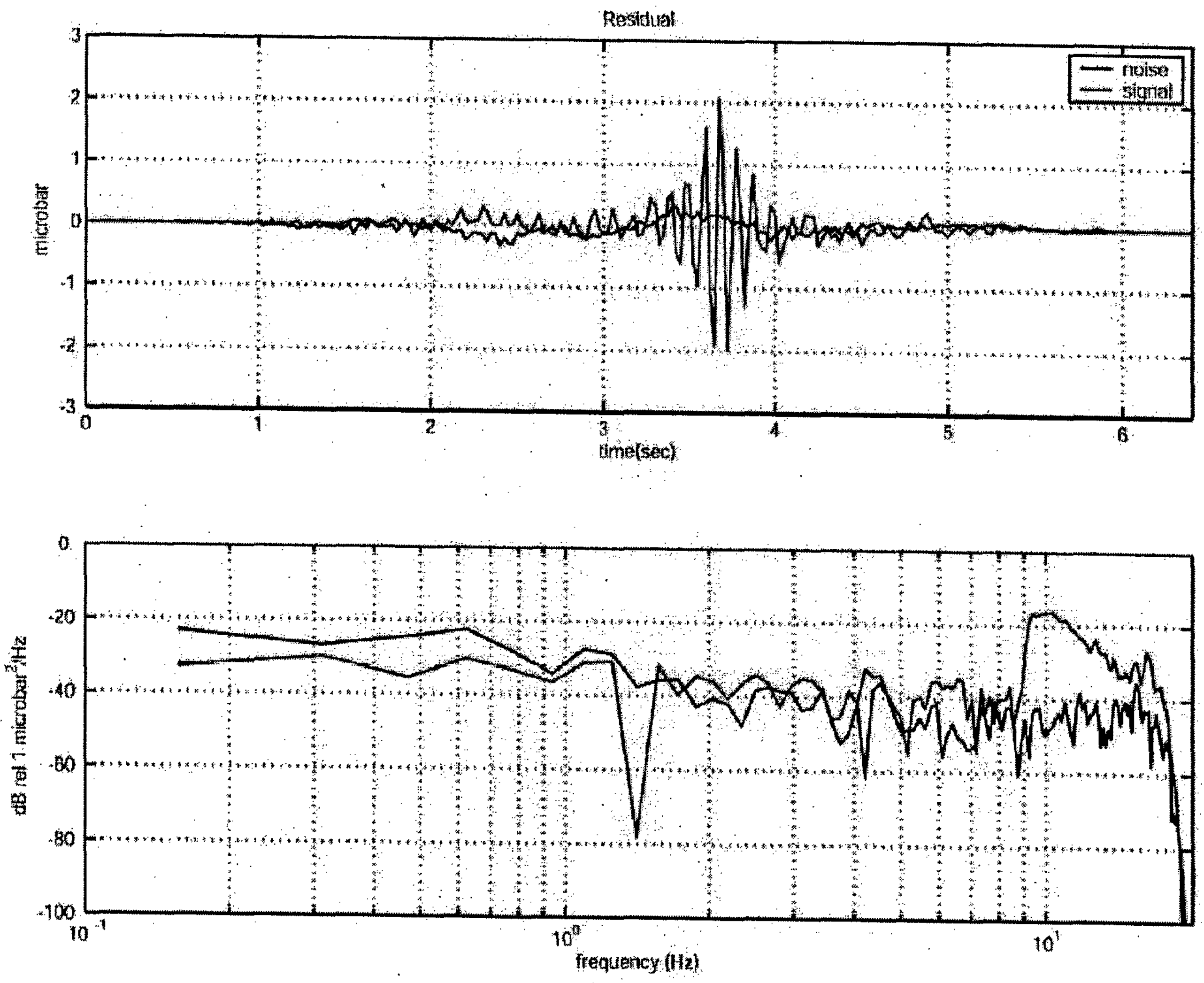
Figure 2.



WAVEGUIDE
Velocity (km/s)
0.345
0.344
0.343
0.342
0.341
0.34
0.339
0.338
0.337
0.336
c
U
c
U
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Frequency (Hz)

Figure 3.


OBSERVATION
FUNDAMENTAL MODE
RESIDUAL
microbar
2
0
-2
-4
2
0
-2
2
1
0
-1
-2
362
364
366
368
370
372
374
376
378
380



Residual
noise
signal
microbar
time(sec)
dB rel 1 microbar^2/Hz
frequency (Hz)

Figure 5.